# APPARATUS AND METHOD FOR DELIVERY OF BIOMASS FUEL

## Background of the Invention

The present invention relates to a method of delivering quantities of biomass fuel to a structure through an external wall of the structure.

"Biomass fuel" refers to fuel that is derived from biological material, either in a raw or processed state. Non-limiting examples of biological material suitable for use as a source of biomass fuel include trees, grass (including yard clippings), wood chippings or sawdust, waste paper, and agricultural waste such as poultry and hog waste.

Because biomass fuel is derived from biological material, it serves as a renewable energy source that can be utilized in place of traditional fossil fuels, such as oil or natural gas. The heat generated from the combustion of biomass fuels can be used directly to heat residential, commercial, and industrial structures. Alternatively, the heat can be used to warm steam in the generation of electricity for other uses.

Wood furnaces have long been used in residential homes as a source of heat, but more general-purpose biomass furnaces capable of generating heat from diverse types of plant-derived fuel are also widely available. These furnaces are often designed to accept biomass fuel in the form of small pellets. The user of a biomass furnace must maintain a supply of these pellets to refill the furnace as needed, typically in the form of large, heavy bags or other storage means. The user of the furnace must purchase the fuel, load it into a vehicle for transportation to the site of use, unload the fuel, and provide storage space until the fuel is needed.

Alternatively, the user of the furnace can contract with a delivery service to provide the fuel as needed. This option, however, requires that the delivery person enter the home or other structure to replenish the fuel supply. In such cases, the occupant of the structure must make arrangements to be onsite when the delivery service arrives, or, alternatively, grant the delivery service access to the structure in his or her absence. Not surprisingly, many owners are reluctant to allow individuals they do not know access to their dwellings or businesses.

The method of the present invention provides a means to circumvent this problem by providing a convenient method of delivering biomass fuel to a residential or other structure without any need for the delivery person to enter into the structure, or for the owner to lift the heavy containers containing the fuel.

The device of the method comprises a hopper mounted to a transportable frame. A forklift can be used to load the hopper into the bed of a delivery vehicle or other vehicle. Delivery of the fuel from the hopper through the delivery hose is accomplished by means of an air pump driven by an internal combustion engine. The pump produces a relatively low pressure of, for example, about 1-10 psi, preferably about 3-7 psi. Both the pump and the engine can be mounted on the transportable frame. The hopper also comprises a sealable inlet opening at the top through which biomass fuel is loaded into the hopper's interior. A second outlet for discharging the hopper's contents is located at the bottom of the hopper, and is controlled by a gate valve. To force the hopper's contents through the discharging outlet and into the delivery hose, the gate valve is opened when the engine and air pumps are running.

In order for the biomass fuel to be delivered to the interior of the home or other structure that may be located outside the home or business, a biomass delivery pipe typically is installed between the biomass fuel chamber and a coupling on the exterior of the structure to which the delivery hose can be connected, although it is possible that the delivery hose could be passed through the wall to reach the fuel chamber or a delivery pipe. Typically, the biomass fuel chamber is a chamber separate from, and located proximate to, the biomass furnace itself. Alternatively, the biomass furnace may itself comprise the fuel chamber to which fuel is delivered by the method of the invention.

The apparatus utilized by the method additionally comprises means to measure the quantity of fuel delivered to the biomass fuel chamber. In a preferred embodiment, when the fuel chamber is full a change in air pressure is recognized and subsequently disengages the air supply. The delivery person will then close the gate valve and disconnect the delivery hose from the external coupling. Other methods for measuring the quantity of fuel delivered and/or when the fuel chamber is full are known to those of skill in the art and may also be used.

The method of the invention therefore provides a convenient way to deliver biomass fuel directly to the interior of a structure without the need for the delivery personnel to enter the structure itself. The owner of the structure, therefore, obtains the convenience of receiving biomass fuel without having to be present for the delivery, and with the added advantage of not having to load and unload the heavy containers of biomass fuel. It is contemplated that the method will be useful not only for residential structures that utilize biomass fuel furnaces, but also for commercial and industrial structures.

The method disclosed herein is designed to deliver biomass fuels for generating energy for use in a wide variety of applications. It is expected that the fuel delivered by the method may be burned, for example, in stoves to generate heat for residential or other structures, or as a source of heat for water heaters, corn driers, pool heaters, and other heating applications.

The biomass fuel delivered by the method may be comprised of differing material. Producers of biomass fuel may alter the content of the fuel in response to changes in the supply and/or pricing of raw materials used in its generation. The content of biomass fuel can also vary geographically, in response to localized differences in the types of material most widely available to create the fuel. In some cases, traditional fossil fuels may be added and comprise a percentage of the finished biomass fuel product.

The size of biomass fuel pellets can also vary depending upon the content of the fuel and its intended use. Typically, the size of biomass fuel pellets may range from granular in size up to about 3/4 in diameter. In a preferred embodiment, the pellets range in size from about 1/8 inch to about 1/2 inch.

The energy content of the biomass fuel will vary with the content of the fuel. The typical range of biomass fuel energy content is from about 5000 to about 15,000 BTU/lb. In a preferred embodiment of the invention, the energy content is from about 7000 to about 11,000 BTU/lb.

Biomass fuel typically burns almost completely under the appropriate conditions, leaving behind only an ash that is often composed primarily of nutrients that are not combustible. This ash, therefore, can be reclaimed for use as fertilizer on crops or cultivated plants.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary perspective view of a biomass fuel delivering apparatus disposed in the bed of a delivery vehicle;

FIG. 2 is an enlarged fragmentary perspective view of the biomass fuel delivering apparatus as viewed from one side thereof;

FIG. 3 is a side elevation of a portions coupling between the biomass fuel delivering apparatus and a residential indeed pipe;

FIG. 4 is an enlarged fragmentary perspective view showing the coupling of FIG. 3 with the in feed pipe and residential fuel chamber;

FIG. 5 is a fragmentary view inside elevation of the fuel chamber, in feed pipe and cover;

FIG. 6 is an enlarged fragmentary perspective view of the fuel chamber and in feed pipe.

FIG. 7 is a picture of a delivery truck as viewed from one side thereof, and comprising a biomass fuel delivering apparatus.

FIG. 8 is a picture of a valve system allowing delivery of biomass fuel from one of three hoppers to a delivery hose.

FIG. 9 is a picture of a truck power take-off used for generating power to operate an air pump on a biomass fuel delivery apparatus.

FIG. 10 is a picture of a truck carrying a biomass fuel delivery apparatus disposed on a weighing scale.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

With initial reference to FIG. 1, a biomass fuel delivering apparatus 11 is positioned within a delivery vehicle 12. The apparatus 11 comprises a sealed hopper 19

that contains the biomass fuel. In the preferred embodiment, hopper 19 comprises a cylindrical main portion 21, a dome-shaped top 22 and a frustroconical lower portion 23. The domed top 22 has a centrally disposed circular opening (not shown) which is sealed by a circular cover 24 that is pivotally mounted to the top 22 by a hinge 25. Sealed top 24 includes a pair of laterally projecting bifurcated ears 26 that interlockably engage a pair of handle clamps 27 when the cover is placed in sealing position. The handle clamps 27 interlockably engage the bifurcated ears 26 and operate in an over-center manner when lowered to clamp the cover 24 in sealed relation to top 22. A resilient annular seal 28 is positioned on the inner peripheral edge of cover 24, and creates an airtight seal with top 22. Dome-shaped top carries a pressure relief valve 29.

In some embodiments, biomass fuel delivery apparatus 11 may comprise more than one hopper 19. In one embodiment, and as shown in Fig. 7, apparatus 11 comprises three hoppers, 95, 96, and 97 respectively. In this embodiment, and as shown in FIG. 8, valves 98, 99, and 100 are used to equilibrate pressure at the top of tanks 95, 96, and 97, respectively.

With reference to FIG. 1, an outlet fitting having a gate valve 30 is disposed at the lower end of the frustroconical portion 23 of hopper 19. Gate valve 30 leads to a biomass fuel delivery hose 31. The gate valve 30 is actuated by a horizontal linkage member 32 (FIG. 2), which is moved by an upright handle member 33. A fixed linkage member 34 is secured to a cross frame member 35. Handle member 33 is pivotally connected to both of the linkage members 32, 34, enabling the user to open the gate valve 30 by pushing handle 33, and to close the gate valve by pulling handle 33.

Apparatus 11 additionally comprises a pair of horizontally disposed, parallel frame members 13, 14 that form the base of apparatus 11. Frame members 13, 14 each comprise an elongated steel tube of rectangular cross section. Frame members 13 and 14 are sized and spaced apart such the prongs of a conventional forklift can enter between them to lift apparatus 11 out of delivery vehicle 12.

With additional reference to FIG. 2, two vertically disposed frame members 15, 16 are secured to (as by welding) and project vertically upward from the frame member 13 at the respective ends thereof. Similarly, vertical frame members 17, 18 are secured to and project upward from horizontal frame member 14. Vertical frame members 15-18 are preferably formed from angle iron with the inner faces thereof facing inward to receive and support a hopper 19.

With continued reference to FIGS. 1 and 2, an air outlet pipe or hose 45 project out of an outlet fitting of air pump 37 (not shown) and is connected to an elbow fitting 46 secured to the side of hopper 19. As indicated above, the outlet pressure of air pump 37 is preferably on the order of 3 psi, and this pressure is communicated through hose 45 and fitting 46 to the inside of sealed hopper 19, exerting pressure in this amount on the biomass fuel disposed within the hopper 19. Further, air pump 37 operates at a comparatively low speed, which results in a pulsating effect that promotes the discharge and delivery of biomass fuel pellets as discussed in further detail below.

With reference to FIG. 1, hopper 19 includes small pressure fitting 47 mounted on the dome shaped top 22. The operator is able to monitor the pressure within hopper 19 utilizing pressure gauge 49, which is connected to fitting 47 via flexible pressure tube 48. As previously discussed, pressure relief valve 29 is also mounted on dome shaped top 22,

and will open if the pressure within hopper 19 reaches a limit of about 25 psi. If the pressure within hopper 19 exceeds 3 psi by any significant amount, however, back pressure will build up through hose 45 to air pump 37 that tends to backload the pump and hence engine 36, causing engine 36 to cease running.

With continued reference to FIGS. 1 and 2, a gasoline engine 36 is mounted to the cross frame member 35. In the preferred embodiment, engine 36 is a relatively small four-cycle internal combustion engine, and in the preferred embodiment has a five-horse power output.

With reference to FIG. 1, battery box 52 is mounted to horizontal frame member 14. Battery box 52 contains battery 51, which starts engine 36 and is maintained in a charged state by the engine generator (not shown). Battery 51 also provides voltage to an indicator circuit as discussed in further detail below.

With reference to FIG. 2, apparatus 11 also comprises a small control panel 53. Panel 53 includes a push button start switch 55 for engine 36, an on-off switch 54 for engine 36, and an indicator light 56 that signals the operator to cease delivering biomass fuel, as described in more detail below.

With reference to Figure 2, engine 36 utilizes a conventional driving connection (not shown) to drive conventional air pump 37. The driving connection consists of a rubber drive wheel connected to engine 36 and a rubber driven wheel connected to air pump 37. The operating speed of air pump 37 is controlled by the relative diameters of the drive and driven wheels. The driving function results from the frictional engagement of the peripheries of the drive and driven wheels. In the preferred embodiment, the speed of air pump 37 is controlled to result in a relatively low pressure output. Air pump 37

includes a pressure regulating valve (not shown) to control its output, which in the preferred embodiment is about 3 psi.

Alternatively, and as shown in FIG. 9, the air pump 37 may be powered by a power take-off 93 located on the underside of truck 12. Power take-off 12 uses the engine (not shown) of truck 12 to drive air pump 37.

With continued reference to FIGS. 1 and 2, an inlet fitting 41 is secured to an inlet of air pump 37, disposed on its top surface. As best shown in FIG. 1, a flexible hose 42 interconnects inlet fitting 41 and a vertically disposed air intake 43. A rain cap 44 prevents rain from entering air intake 43.

With reference to FIG. 1, it is helpful to maintain the pellets in as dry a state as possible to ensure that the biomass fuel pellets flow smoothly during discharge. Therefore, the air inlet of air intake 43, which bears reference numeral 43a (the portion covered by rain cap 44), is of smaller inside diameter than that of the main body of air intake 43. As such, when air is drawn through the inlet 43a, it expands into the main body portion, reducing pressure and causing moisture in the air to condense before entering the air pump.

During the biofuel delivery process, dust particles from the biomass fuel can build up during discharge and result in clogging of air pump 37. In some embodiments, therefore, and as shown in FIG. 10, apparatus 11 also includes a small canister 101, which may be made of steel, that is in fluid communication with pump 37. Disposed within canister 31 is a filter (not shown) that removes particles before reaching pump 37.

An additional issue that can be encountered during biomass fuel discharge is the presence of residual biomass fuel 86 within delivery hose 31 after fuel delivery has been

completed. Therefore, with respect to FIG. 10, some embodiments of the invention incorporate large canister 102, which may also be made of steel, that is in fluid communication with delivery hose 31. Upon completion of fuel discharge, the operator of apparatus 11 can reverse the flow of air using air pump 37 to create a vacuum in delivery hose 31. The vacuum causes residual fuel left in hose 31 to flow under pressure into canister 102, where it may be stored and reclaimed for future use. Alternatively, the operator may use air pump 37 to generate a vacuum in delivery hose 31 such that canister 102 collects ash or other residual material located from an ashpot. This embodiment, therefore, allows the operator to provide the additional service of removing waste material during the same scheduled time that fuel is delivered.

The length of biomass fuel delivery hose 31 is designed such that it can reach from the biomass fuel delivery apparatus 11 to the external coupling of a residence or other structure as described in further detail below. In the preferred embodiment, biomass fuel delivery hose 31 is 150 feet in length.

With reference to FIG. 4, the extreme end of hose 31 terminates in a mechanical coupling 63 that will be discussed in further detail below.

With reference to FIG. 3, hose coupling 63 is sealably interconnectible with an external residence coupling bearing the general reference numeral 64. Coupling 64 spans external residential wall 65, and includes an external portion including an internally threaded coupling 67 and a flange 68 that lies against the residential wall 65, as well as an internal portion taking the form of a pipe 66. Normally, an externally threaded plug 69 is screwed into the coupling 67 to close it. A square projecting boss 69a enables the plug 69 to be wrenched in or out. The operator of delivery apparatus 11 removes plug

69 prior to commencing delivery of the biomass fuel, and replaces it with a threaded coupling 71 having an externally threaded portion 71a that screws into the coupling 67 and a toothed ring 71b that is used to grip the coupling 71. Outwardly of toothed ring 71b is a connecting portion 71c having an annular groove 71d.

With combined reference to FIGS. 3 and 4, hose coupling 63 is sized to fit over coupling 71. Hose coupling 63 includes a sealing O-ring (not shown) that seats into the annular groove 71d. Coupling 63 has a pair of clamping wings 63a, 63b which, when pressed flat against coupling 63, causes the O-ring to compressibly seal against the annular groove 71d. Outward lifting of the wings 63a, 63b releases the internal O-ring and permits the coupling 63 to be removed from coupling 64.

With continued reference to FIG. 4, coupling 64 is located in proximity to a biomass fuel bin 72, which in turn is located adjacent a biomass fuel furnace (not shown). Biomass fuel furnaces are often located in the lower level of the residential or other structure, and the coupling 64 is accordingly depicted in FIG. 4 in a position relatively close to the ground where it is accessible to the biomass fuel delivery operator.

In some embodiments, fuel bin 72 may not be located within a residence or other structure. In these cases, bin 72 may be located outdoors. In this case, coupling 71 may be located directly on bin 72, and coupling 63 is sized to fit over coupling 71. Alternatively, bin 72 may not have a coupling 71, and fuel may be discharged directly to the interior of the bin via an opening such as a hatch or door disposed on the exterior surface of bin 72.

With reference to FIGS. 5 and 6, bin 72 includes a flexible dust/filter bag 73 to accommodate the biomass fuel delivering apparatus 11. Flexible dust/filter bag 73 has a

large open lower end with an elastic periphery that fits over the top opening of bin 72, and a smaller top elastic opening that receives a flexible biomass fuel delivery pipe 74. With reference to FIG. 4, flexible pipe 74 is connected to a rigid pipe 75 through an elbow fitting 76. Rigid pipe 75 is secured to a floor joist 77 or similar structure by a plurality of straps 78. With additional reference to FIG. 3, pipe 75 is coupled to the internal pipe 66 of coupling 64 by a pipe clamp 79.

The preferred embodiment also comprises means to signal the operator when the level of biomass fuel within bin 72 is full so that delivery of the fuel should be stopped. When the fuel chamber is full a change in air pressure is recognized and subsequently disengages the air supply. The delivery person will then close the gate valve and disconnect the delivery hose from the external coupling.

Alternatively, and as shown in FIG. 10, apparatus 11 sits on weighing scale 94. Weighing scale 94 is itself disposed on the bed of truck 12. The weighing scale can comprise any suitable scale, such as a NORAC® scale, that is NTEP approved for selling products by weight. Scale 94 is designed to weigh the entire apparatus 11, including the biomass fuel 86 disposed within hopper 19. In this embodiment, the apparatus 11 is weighed using scale 94 prior to commencing the fuel delivery process. The operator then monitors the weight of apparatus 11 during fuel delivery, and stops the biomass fuel discharge after a preselected weight of biomass fuel 86 has been discharged from hopper 19. This embodiment, therefore, allows the operator to deliver an amount by weight of biomass fuel 86. Other methods for measuring the quantity of fuel delivered and/or when the fuel chamber is full are known to those of skill in the art and may also be used.

The portability of apparatus 11 allows it to be transported from location to location via a delivery vehicle 12, such as, for example, a pick-up truck. Thus, apparatus 11 is ideal for the method of the invention, in which biomass fuel is delivered to varying locations. It is contemplated that deliveries can be made at preestablished intervals. A step-by-step exemplification of the delivery process now follows.

At the beginning of the delivery route, the operator fills hopper 19 with a quantity of biomass fuel selected to ensure that sufficient fuel is available for all deliveries on the route. To fill the hopper 19, the operator releases the clamping valves 27 and lifts the cover 24 to the position shown in FIG. 1. The filling may be accomplished by an overhead hopper under which the apparatus 11 is driven, or a conveyor or delivery hose that can be brought to the mouth of hopper 19. Handle 33 is pulled to close the gate valve 30 prior to delivery. After hopper 19 is filled to the preselected level, the operator closes cover 24, which is then sealably clamped over the hopper opening using handles 27.

After the hopper has been transported to a location where biomass fuel is to be delivered, the operator starts engine 36 by moving on-off switch 54 to the on position and pressing start switch 55. The activation of the engine causes air pump 37 to start delivering air under pressure through pipe 45 to the top of hopper 19. Only a short time is required for the pressure inside hopper 19 to reach the relatively low operating pressure of about 3 psi.

Next, the operator unrolls supply hose 31 from the bed of delivery vehicle 12 and connects an end of the hose to the external house coupling 64 by removing plug 69 of house coupling 65 and threadably inserting threaded delivery coupling 71. Delivery hose

coupling 63 is then placed over threaded coupling 71 and wings 63a, 63b are moved to the clamping position.

The operator then returns to biomass fuel delivery apparatus 11, and pushes handle 33 to open gate valve 30. Air pump 37 continues to run at this time and produces pulses of air under pressure. Biomass fuel pellets flows out of hopper 19 through the gate valve into delivery hose 31 under the force of gravity. The biomass fuel pellets are driven through delivery hose 31 under the pressure generated by air pump 37. The biomass fuel pellets flow through coupling 64, pipes 75 and 74 and then into the biomass fuel bin 72 within the structure.

Since biomass fuel pellets can accumulate dust during transportation due to abrasion between the pellets, filter bag 73 is used to contain the dust while the pellets are delivered to bin 72, while still allowing air displaced by the fuel to escape. Normally, filter bag 73 remains in the position shown in FIG. 5, and there is generally no need to remove it.

The biomass fuel delivery continues with the operator at the site of apparatus 11 in close proximity to handle 33. When the level of biomass fuel inside of fuel bin 72 is full, the operator pulls handle 33 to close the hopper gate valve 30, stopping the delivery of biomass fuel to bin 72. Although the gate valve is closed, air under pressure continues to pass through it, and engine 36 is permitted to run until all of the biomass fuel in hose 31 is fully discharged. Engine 36 is then stopped by turning switch 55 to the off position. The operator then removes delivery hose coupling 63 from the external house coupling 65. Delivery hose 31 is recoiled into the bed of delivery vehicle 12, and the operator then drives to the next delivery location. Alternatively, there may be an automatic shut off for

the compressor. For example, this could be activated when an increase in pressure in the air hose is sensed, which would indicate that the fuel chamber has been filled.

The disclosed invention operates to complete the biomass fuel delivery process quickly and efficiently, and has the additional advantage of allowing the delivery to take place without the operator entering the residence or other structure. Rather, the operator merely moves between the delivery vehicle and external house coupling, and does not have to unload and carry several heavy biomass fuel bags from the delivery vehicle into the residence, or to open the bags of and lift and empty them into the biomass fuel bin. The inventive apparatus and system also eliminates the difficulties associated with loading, transporting, unloading, carrying and emptying biomass fuel bags.